Module 2: Automatic Vehicle Location Systems

M o d u l e   2

A u t o m a t i c   V e h i c l e

L o c a t i o n   S y s t e m s

Transit Management 2-1

TRANSIT MANAGEMENT TRAINING ROADMAP
Module 1: Introduction to ITS and APTS
Module 2: Automatic Vehicle Location Systems
Module 3: Automated Transit Information
Module 4: Transit Telecommunications
Module 5: Transit Operations Software
Module 6: Paratransit Computer-Aided Dispatch
Module 7: Electronic Fare Payment
Module 8: Technologies for Small Urban and Rural Transit   Systems
Module 9: Stages of ITS Project Deployment
Module 10: What Can ITS Do for Me?

State-of-the-art Location Technologies:
- GPS
- Differential GPS
- other
- combination systems

Data Transmission to dispatch:
- polling
- exception reporting

Module 2: Automatic Vehicle Location Systems

Introduction

Slide:
Goals

> # Goals
>
> · To provide an overview of automatic vehicle location technology
>
> · To introduce methods of data transmission to dispatch
>
> *Transit Management 2-2*

Goals   In looking at location technology, this module will provide an overview of:
- the state-of-the-art automatic vehicle location technology:
  ◊ Global Positioning System (GPS)
- the other types of automatic vehicle location technology:
  ◊ signpost and odometer
  ◊ radionavigation/location
  ◊ dead reckoning

The module will also introduce the two most common methods of data transmission from the vehicle to dispatch:
- polling
- exception reporting

Introduction, Continued

**Module
objectives**

Given a set of student materials, students will identify the most appropriate AVL system for their agency.

Given an APTS Technology Reference table, students will list three benefits of using an AVL system in their agency.

**Slide:
Module Outline**

Module Outline

- What is AVL?
- Location technology
- Data transmission to dispatch
- Custom course notes

2-4
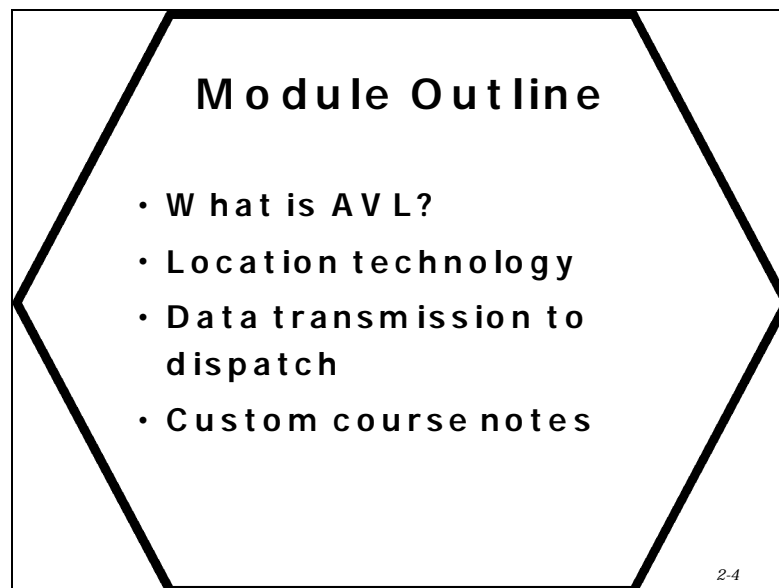
**AVL has
two parts**

An Automatic Vehicle Location (AVL) system is a technology that allows an agency to improve its fleet management.
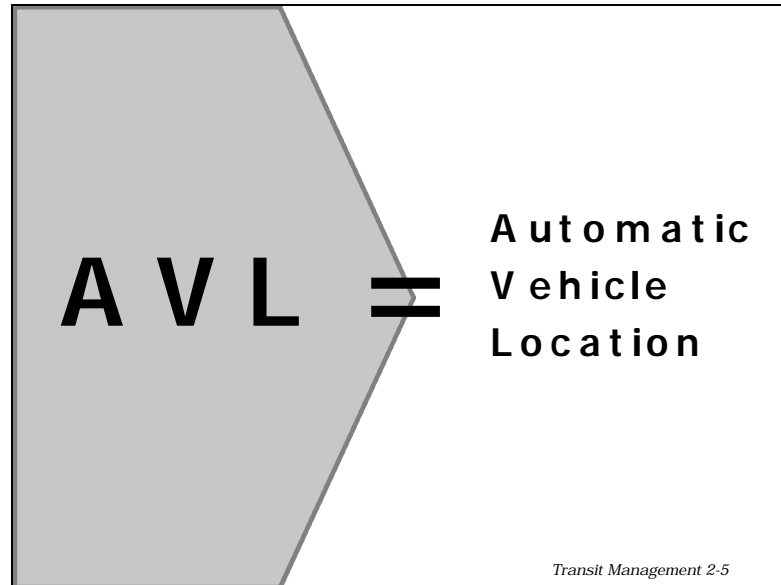
Specifically, these systems are usually composed of two parts:
- locating the vehicle
- communicating the location to a central dispatch

What Is AVL?

**Slide:
Automatic
Vehicle
Location**

AVL = Automatic Vehicle Location

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Continued on next page

What Is AVL?, Continued

Slide:
What Is AVL?

```
 _____
|                                         \
|          W hat Is A V L ?                 >
|_____/
|                                          |
|   · A computer based tracking            |
|     system                               |
|                                          |
|   · Measures real-time position          |
|     of vehicle                           |
|                                          |
|   · Relays information to central        |
|     location                             |
|                                          |
|                        Transit Management 2-6 |
|_____|
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What is AVL?   AVL systems:
- are computer-based vehicle tracking systems
- use a positioning system
  ◊ usually GPS
  ◊ but also could use sign post and odometer, or dead reckoning
- transmit vehicle location to the transit dispatch center as required
- can also minimize voice transmissions by providing location data messages

AVL vs. AVM   Automatic Vehicle Location (AVL) and Automatic Vehicle Monitoring (AVM) are sometimes used interchangeably, but in general:

- AVL includes vehicle location and tracking systems.

- AVM couples AVL location data with information on vehicle status and operating conditions, such as oil pressure, engine temperature, etc.

What Is AVL?, Continued

Real-time tracking

The two keys to an Automatic Vehicle Location system – locating the vehicle and communicating that information back to a central dispatch – work together to form a real-time computer-based tracking system.

AVL systems generally use technology on the vehicle and at the central dispatch to:
- calculate the vehicle location on board
- store the position information on board for a short time
  ◊ from a few seconds to several minutes, or can depend on an outside trigger
- inform the dispatch of the vehicle position
  ◊ sometimes at set time intervals or locations
  ◊ sometimes the position information is sent to the dispatch only when dispatch needs the information

AVL uses

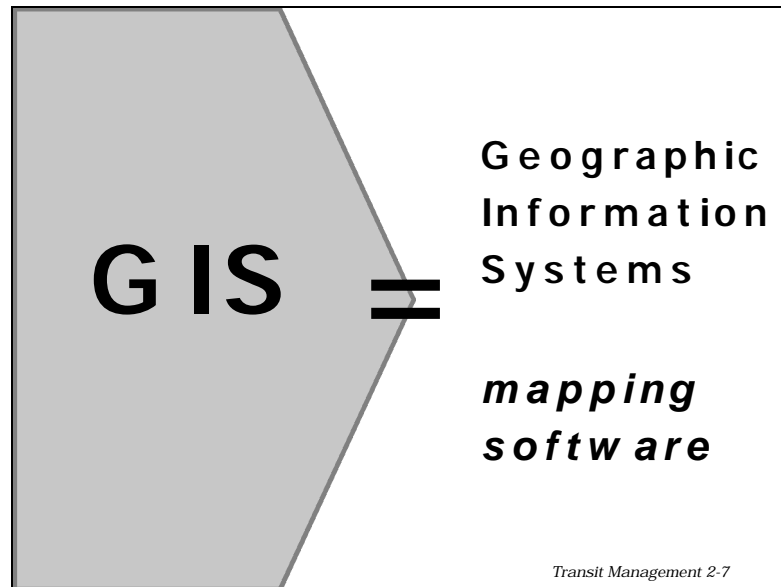AVL systems are designed to help agencies:
- dispatch
- track
- communicate
- manage mobile assets (e.g., transit vehicles, equipment inventory, equipment repair, and human resources)
- have records of where vehicles were at a given time and date

What Is AVL?, Continued

Slide: GIS

GIS = Geographic Information Systems

mapping software

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GIS   A geographic information system is a special type of computerized database management system in which databases are related to one another based on a common set of locational coordinates. This relationship allows users to make queries and selections of database records based on both geographic proximity and attribute values.

In the past few years, the use of GIS by public transportation systems has increased significantly. The most frequent use has been in the application of urban bus service route and schedule information maintenance and presentation of this information to customers.
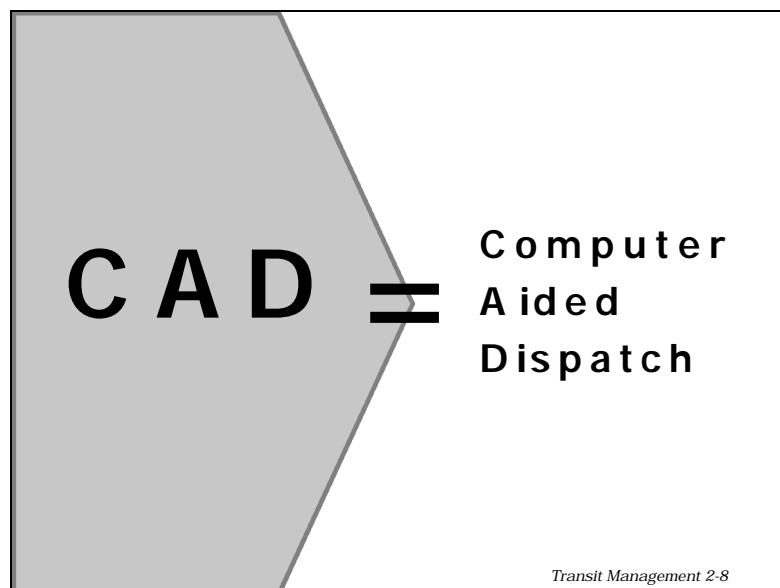
GIS enables the effective working of an AVL system.

Source: APTS State of the Art Update '98, p. xii

What Is AVL?, Continued

Slide: CAD

C A D = Computer Aided Dispatch

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CAD   Computer-aided dispatch (CAD) is a type of transit operations software that can combine with AVL to facilitate tracking the on-time status of each vehicle in a fleet. Not only do operators and dispatchers benefit from regular updating of on-time status, but customers benefit as well through the information systems.

Source: APTS State of the Art Update '98, p. xv

What Is AVL?, Continued

Slide: AVL Benefits

A V L   B e n e f i t s

· S a f e t y
· O p e r a t i o n s
· C o s t   b e n e f i t s
· C u s t o m e r   s e r v i c e

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Slide: Safety Benefits

S a f e t y   B e n e f i t s

· T i m e l y   d e c i s i o n s
· Q u i c k e r   r e s p o n s e s
· Q u i c k e r   n o t i c e   o f   p r o b l e m s
· I n c r e a s e d   d r i v e r   a n d
  p a s s e n g e r   s a f e t y

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What Is AVL?, Continued

Increased safety   AVL increases safety by providing:
- timely decisions and response in an emergency
  - ◊ e.g., if a passenger has a medical emergency, AVL can show dispatch exactly where the vehicle is and pass that information to an emergency vehicle more quickly

- quicker responses to disruptions in schedule
  - ◊ e.g., traffic congestion, bus running late, etc.
  - ◊ e.g., AVL information passed on to the passenger, such as a sudden snowstorm causing a particular trolley to be 20 minutes late, can help prevent that passenger from waiting on a platform late at night

- quicker notice of mechanical problems with vehicles
  - ◊ e.g., dispatch knows when and where to send a replacement bus for a bus with a flat tire
  - ◊ e.g., when combined with in-vehicle diagnostics, dispatch knows when to send a replacement bus before it has the flat tire

- increased driver and passenger safety and security
  - ◊ e.g., a silent alarm can be sent to dispatch if a dangerous passenger is threatening other passengers, and dispatch can contact the appropriate authorities

What Is AVL?, Continued

APTS reports   Safety benefits reported about APTS in the benefits document on the U.S. DOT APTS web site include:

- Several instances in cities with AVL equipped buses where bus operators have observed accidents, crimes, or other situations outside the bus, which warrant quick response by emergency personnel. The AVL system's communication and location capability has allowed the emergency personnel to be quickly notified and directed to the exact location of the trouble.

- Kansas City Area Transit Authority (KCATA) dispatchers estimate that response times to bus operator calls for assistance have been reduced from 7-15 minutes to 3-4 minutes.

- Public safety alerts can be forwarded to buses to avoid a high risk area:
  ◊ e.g., buses can be rerouted if a fire might endanger a route

- The location of a bus can be forwarded to public safety agencies if an operator detects and signals a problem.

What Is AVL?, Continued

Increased safety example

Denver Regional Transportation District (RTD) installed an AVL computer-aided dispatch system, and reported the following:

- In Denver, a man who had just robbed a convenience store was observed to have boarded an RTD bus. The police informed the dispatcher, who used the Computer-Aided-Dispatch AVL system to identify which bus the suspect would likely have boarded. The transit control head's message capability was used to confirm the suspect's presence on the bus. The police were then directed to a point where the bus could be intercepted. The suspect was apprehended.

- In Denver, a man brandishing a knife was thought to have boarded an RTD bus. The driver signaled to dispatch using the silent alarm. Through the CAD AVL system, the correct bus was identified, the police notified, and the man arrested.

- Also in Denver, a bus passenger had a seizure. RTD was able to notify emergency response personnel of the incident and its location, and an ambulance was at the scene within eight minutes.

What Is AVL?, Continued

Slide:
Operations
Benefits

> # Operations Benefits
>
> - **Increased dispatching**
>   **efficiency**
> - **Improved planning ability**
> - **Improved problem prevention**
>
> *Transit Management 2-11*

Operations
benefits

Benefits include:
- Increased dispatching efficiency
  ◊ e.g., AVL helps to keep vehicle and dispatch clocks synchronized.
- Improved planning ability
  ◊ e.g., planners have more information available to them.
- Improved problem prevention
  ◊ e.g., AVL coupled with vehicle monitoring helps to identify vehicle problems before they become serious.

Continued on next page

What Is AVL?, Continued

Improved operations examples

Operational benefits reported in the benefits document on the U.S. DOT APTS web site include:

- Milwaukee County Transit System claims that on-time performance has improved from 90% to 94% after implementing their AVL system, even though the system is not fully operational.

- The Mass Transit Administration of Maryland reported a 23% increase in on-time performance of buses in Baltimore in their test of AVL equipped buses on a few routes.

- Kansas City Area Transit Authority's (KCATA's) on-time performance (from one minute early to three minutes late) improved from 80% to 90% after AVL installation.

What Is AVL?, Continued

Slide: Cost Benefits

> # Cost Benefits
>
> · Reduced operating costs
>
> · Reduced number of buses needed
>
> · Lower cost of information collection than manual methods
>
> *Transit Management 2-12*

Decreased costs examples

Cost benefits reported about APTS in the benefits document on the U.S. DOT APTS web site include:

- A large transit authority has estimated that AVL generated data would allow them to reduce the number of schedule adherence checkers and save approximately $1.5 million per year.

- Although KCATA did not eliminate street supervisory personnel, they achieved some savings because with AVL, absences or temporary reassignment of supervisors were less of a problem.

- London, Ontario's AVL system will provide schedule adherence on a continuing basis, thus saving the $40,000 to $50,000 previously spent on each schedule adherence survey.

- Milwaukee County Transit System plans to re-deploy a number of street supervisors when the CAD AVL system is fully operational.

What Is AVL?, Continued

Slide: Service Benefits

> # Service Benefits
>
> · Improved service to customers
>
> · More accurate passenger information
>
> · Increased adherence to schedule
>
> · More reliable service
>
> · Improved complaint resolution
>
> *Transit Management 2-13*

Schedule adherence

A number of transit operators have claimed improved schedule adherence after AVL implementation, including:
- County of Lackawanna Transit System (Scranton, PA)
- Broward County Division of Mass Transit (FL)
- Beaver County Transit Authority (Rochester, PA)

Complaint resolution

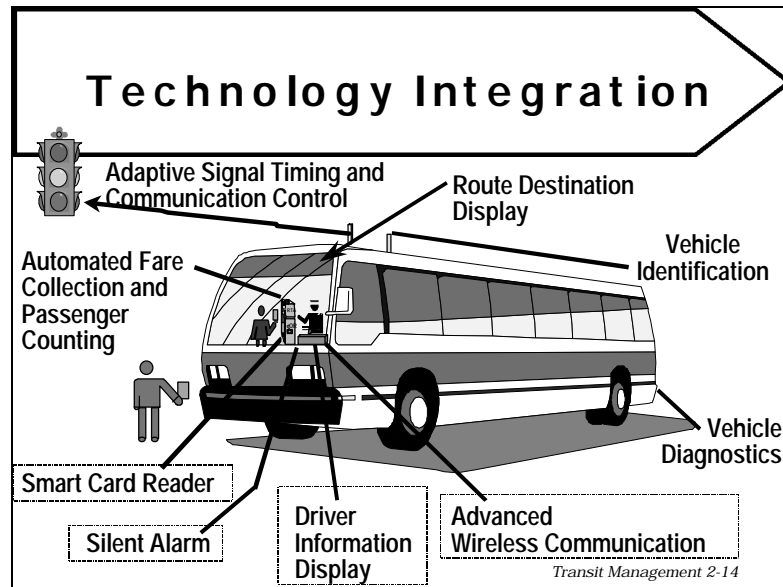Also reported in the benefits document on the U.S. DOT APTS web site:

- In Denver, a bus operator initially was not paid for a day that she worked. The CAD AVL log-in requirement proved that she did work on that day.

- In Milwaukee, a passenger complained that a bus had left a stop too early, a fact that the bus operator disputed. The playback capability of the CAD AVL system corroborated the operator's claim.

What Is AVL?, Continued

**Slide:
Technology
Integration**

Technology Integration

Adaptive Signal Timing and Communication Control

Route Destination Display

Vehicle Identification

Automated Fare Collection and Passenger Counting

Smart Card Reader

Silent Alarm

Driver Information Display

Advanced Wireless Communication

Vehicle Diagnostics

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**Technology
integration**   Automatic Vehicle Location systems are currently among the most popular of the APTS technology applications because the information they provide can be linked to or drive other applications.

For instance, almost all AVL systems being installed now can be linked to some kind of advanced traveler information system because the information from the AVL system can feed the advanced traveler information system.

The integration of transit and highway traveler information systems is an important element of a metropolitan ITS system.

What Is AVL?, Continued

Considerations   If you are considering an AVL system, you will also want to consider some of the technologies and applications that can be integrated with it, including:

- traveler information systems
- schedule adherence monitoring
- schedule planning
- silent alarm
- vehicle component monitoring systems
  ◊ e.g., engine conditions
- automatic passenger counters
- computer-aided dispatch
- traffic signal preferential treatment
- electronic fare payment systems
- geographic information systems (GIS) for mapping

Most of these technologies cannot stand alone. They rely on telecommunications to convey the information from where it is created to where it is needed or used. Telecommunications, then, is the glue that binds all of this technology together.

Most agencies cannot install everything at once, since the scale of such a project would be too large, but you should plan how future systems might be integrated.
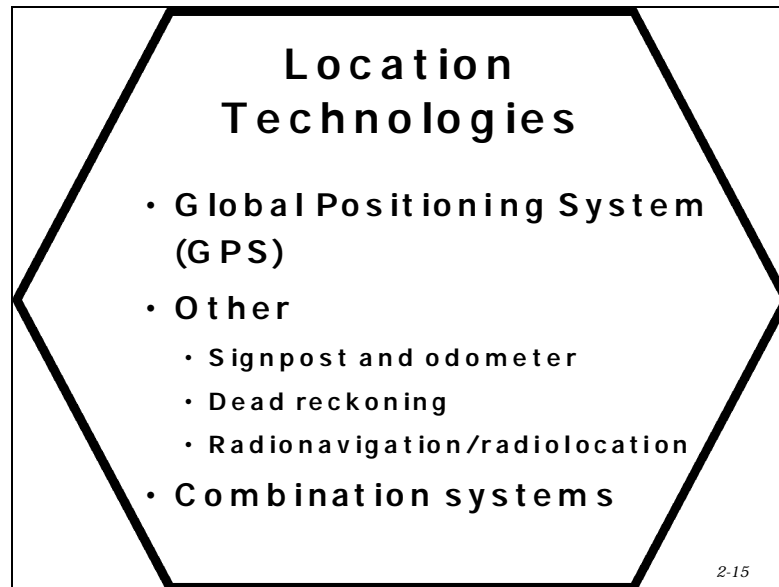
Silent alarm   Most AVL systems include a silent alarm, i.e., a silent way for the operator to signal dispatch in the case of an emergency. Silent alarms are relatively inexpensive when coupled with an AVL system.

Bus operators in transit systems with AVL report a greatly increased feeling of security with the silent alarm, listen-in-feature, and rapid response capability that the system provides.

Location Technologies

Location Technologies

· **Global Positioning System (GPS)**

· **Other**
  · **Signpost and odometer**
  · **Dead reckoning**
  · **Radionavigation/radiolocation**
· **Combination systems**

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Location technology

Each system employs one or more location technology. State-of-the-art location technology for transit is:
• Global Positioning System (GPS)

Other location technologies include:
• Signpost
• Dead-reckoning (using odometer and compass)
• Radiolocation (using other navigation systems or communications systems)

In some cases, a single technology is sufficient for position determination. Often, however, the primary location technology must be supplemented with another, due to either the environment in which the system operates or the demands of the agency's application of the AVL system.

This course focuses on GPS and other technologies that combine to supplement GPS.

Location Technologies, Continued

Slide: State-of-the-Art Global Positioning System

> ### State-of-the-Art Global Positioning System
>
> - Signals transmit via satellite network
> - Antenna on roof of bus
> - Receiver aboard bus
> - Bus transmits location to dispatch

What is Global Positioning System?

GPS is a state-of-the-art radionavigation system. Twenty-four GPS satellites orbit 18,000 kilometers above the earth transmitting signals. From these signals, AVL provides the technology to calculate the location of a vehicle. The location data is transmitted to the monitoring station via a communications system.

Global positioning (GPS) works anywhere the satellite signals will reach (which is any location where a minimum of three satellites is in view to send and retrieve signals). The coverage area includes all of North America. The satellite Master Control facility is located at Falcon Air Force Base in Colorado.

A GPS/AVL system can provide up to five reports per second so the dispatcher can receive continuous feedback from the fleet. This information can be integrated with an existing computer-aided dispatch program or used for display on an electronic map.

GPS was designed as a Defense Department method of location for the armed forces. The DoD wants to limit accuracy for civilian use, so it's currently only accurate to 100 meters. Full accuracy may be available in the future (within 20 meters or better).

Continued on next page

Location Technologies, Continued

Slide: State-of-the-Art Differential GPS

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│  │   S t a t e - o f - t h e - A rt  ──────►  │
│  │   D iffe re n t ia l G PS         │        │
│  └──────────────────────────────────┘        │
│                                               │
│   · Know n posit ion "correct s"              │
│     GPS                                       │
│                                               │
│   · More accurate than GPS                    │
│                                               │
│   · Most com m on t ransit                    │
│     applicat ion of GPS in U.S .              │
│                                               │
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Differential GPS

To improve the accuracy of GPS, differential GPS is used.

A differential GPS system includes a receiver placed at a stationary surveyed site (a "known position") to account for errors in position.
• A ground beacon can also provide the differential signal.

Applying the correction information to the GPS location information can greatly improve accuracy (to 20 meters or better) over the traditional GPS systems (which are accurate to 100 meters).

State-of-the-art transit use of GPS

The most current common transit application of global positioning systems uses differential GPS.

Location Technologies, Continued

**Slide: GPS
Advantages**

> # GPS Advantages
>
> · Works in a wide area
>
> · More robust than signpost
>   and odometer
>
> · Only vehicle cost is the
>   receiver/antenna/processor
>
> *Transit Management 2-18*

GPS advantages   Compared to the other location technologies, GPS has several significant
advantages, including:
- It works in a wide area.
- It is more robust and requires less maintenance than signpost and odometer.
- The satellite service is free – there is no rental fee, so your cost for the
  location technology is the equipment. In-vehicle costs (the costs of GPS
  location technology by itself) include:
  ◊ receiver
  ◊ antenna
  ◊ processor: sometimes called a vehicle logic unit (VLU)

Location Technologies, Continued

**Slide: GPS
Disadvantages**

**G P S
D i s a d v a n t a g e s**

· T r e e s   a n d   b u i l d i n g s   m a y
  i m p a c t   p e r f o r m a n c e

· P r o b l e m   a r e a s   n e e d
  t o   c o m b i n e   w i t h
  a n o t h e r   s y s t e m

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**GPS
disadvantages**

There are some disadvantages to GPS:
• It cannot reach underground (tunnels).
• It can be interrupted by tall buildings or trees.

The strengths of GPS cover the weaknesses of some of the other location
technologies, and can pair nicely to work together in a combination system.
• For example, in the trouble spots of an urban canyon, where the GPS
  satellites may be unreliable, a few signposts can be placed to locate the
  vehicle until it leaves the problem area.

Lessons learned

According to *Update '98* (page 2-20), the Milwaukee Transit System (MTS)
in purchasing an AVL system advises:
• "careful definition of clear, reasonable objectives that meet the needs of the
  area and a close, positive working relationship with the vendor. Prepare a
  detailed specification for prospective vendors, including a phased acceptance
  testing program, and be realistic about the timetable for completion."

Continued on next page

Location Technologies, Continued

**Slide:
Alternatives**

```
                    A lternatives

            · Signpost and odometer
            · Dead reckoning
            · Radiolocation




                                    Transit Management 2-20
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**Alternative:
Signpost and
odometer**

Signpost and odometer is a well-established technology that is becoming less popular for new applications or systems in this country. Signpost remains popular in Europe and Japan.

A series of radio beacons are mounted along a route on utility poles. These beacons have a unique ID and send out a low-powered signal that can be detected by a vehicle fitted with a receiver. When it is time for the vehicle to report, it relays the ID of the last signpost it passed to the control center, along with a measure (from the odometer) of the distance it traveled since passing the signpost. In this approach, the bus can send signals to dispatch at any point along the route.

Under an alternative strategy, it is the bus that has the unique ID, and the signposts receive the signals from the bus. This alternative method reduces both radio traffic and the need for many reserved radio frequencies, since the stationary signposts may be hard-wired into the signpost-dispatch center wireline communication link.

Location Technologies, Continued

Signpost and odometer advantages	Compared to the other basic types of AVL location technology, signpost and odometer is one of the earliest, most proven technologies. The system has been in use with little change since 1978 when Seattle Metro used it to improve the accuracy of their bus route data. Because of this, the signpost and odometer method of location technology has been well tested. In addition, signpost systems work in "trouble spots" like tunnels and tall buildings.
Signpost and odometer disadvantages	On the negative side, signpost and odometer is the "low-tech" solution that often requires high maintenance of the signposts. Signposts can be placed only at certain locations, and the system cannot track a bus off route. Most newer installations are not using signpost and odometer alone. Signpost and odometer combined with another technology can offer several "best of both worlds" advantages.
Alternative: Dead reckoning	In general, dead reckoning systems start with a known starting point and then calculate position based on direction and distance traveled. • vehicle distance traveled can come from the vehicle odometer • direction of travel can come from a compass or from wheel direction
Compass and wheel sensors	In an AVL system that uses dead reckoning, a digitally compensated solid state compass and wheel sensors are typically installed in each vehicle. These are used to measure heading (direction) and distance to "dead reckon" a new position from a previous position.
Inertial gyroscopes	New technology that only recently has become available includes low-cost inertial sensors (gyroscopes) for vehicles. • In such systems, fiber optic ring gyro techniques are used to sense heading information. ◊ e.g., Andrews Corp. Gyroscope Navigstar • The distance traveled information, like for the electronic compass, comes from wheel/odometer information.

Location Technologies, Continued

Dead reckoning calculations	The vehicle's starting position is plotted when the sensors are first mounted in the vehicle. The system determines a new position for the vehicle by using the previous position and "drawing a line" to the new position based on the vehicle's heading and the distance it has traveled.

Dead reckoning accuracy	A good dead reckoning system can locate with only a one or two percent error rate. • Consider that for every mile driven, the location can be off by up to 100 feet. If you drive 50 miles, the location derived by this system can be blocks away from the vehicle's actual position. • Therefore the system must be "zeroed" out at the vehicle starting point.

Alternative: Triangulation with radio towers	Triangulation can be used in communication systems for radiolocation. One such system operates on radio frequencies in the 900 MHz band. Transmitting and receiving towers are placed strategically throughout a region. By triangulating on the signal transmitted from the vehicle at the receiving towers, a vehicle can be located to within 150 feet. Positions are relayed back to base stations where they are shown on display maps. • PacTel Teletrac in Los Angeles provides service that operates on frequencies in the 900 MHz band and utilizes radio towers. Transmitting and receiving towers are placed strategically throughout the region.

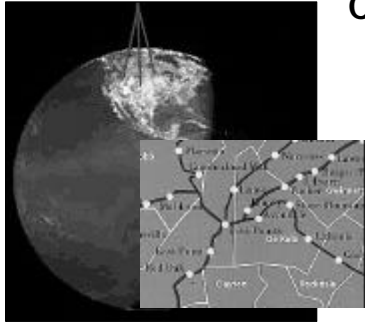|	
Alternative: LORAN-C: Radionavigation	LOng RANge aid to navigation, the present version of which is known as Loran-C, is a land-based radionavigation system that uses low-frequency waves to provide signal coverage. LORAN-C determines location based upon the reception of transmissions and associated timing. LORAN-C is a "fading technology" or a "legacy system."

Continued on next page

Location Technologies, Continued

**Slide:
Combination
Systems: GPS
& Dead
Reckoning**

Combination Systems:
GPS & Dead Reckoning

Complement
each other

- GPS improves
  accuracy of dead
  reckoning
- Dead reckoning
  increases GPS
  coverage

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**Technology
integration:
Dead reckoning
and GPS**

Dead reckoning, by itself, drifts over time. GPS can correct that.

Some AVL systems combine dead reckoning, map matching and GPS: dead
reckoning is combined with map matching to keep the vehicle's location
matched to a map, and with GPS to correct the occasional errors.

A combination system is a more accurate solution, but is more costly than
dead reckoning alone.

GPS and dead reckoning complement each other well.

**Combination
systems**

Some companies have improved dead reckoning by adding an application of a
geographic information system (GIS) called "Mapmatching." Mapmatching
constantly compares the indicated vehicle position to a street location on an
electronic copy of a map.

Continued on next page

Location Technologies, Continued

Technology integration: Geographic information systems (GIS)

In a simple case, if the AVL system says the vehicle is heading due east, but the map shows only a road heading a bit off due east, map matching can correct the location of the vehicle to the road.
- If a correction is performed often enough, e.g., every one or two seconds, it can eliminate the small errors that will occur.
- Mapmatching also recognizes that the vehicle is not always on a road and takes this into account when making corrections.

Slide: Other Combination Systems

> # Other Combination Systems
>
> - **GPS & Signpost**
>   - Work well as a complementary system
>   - Trees, buildings, and tunnels, which obstruct GPS, are not a problem
>
> *Transit Management 2-22*

GPS and signpost

Signpost systems combine particularly well with GPS because the two complement each other.
- GPS doesn't work in tunnels and urban canyons; signposts can be placed directly in these trouble spots.

Data Transmission to Dispatch

**Slide:
Data Trans-
mission to
Dispatch**

Data Transmission to Dispatch

- Polling
- Exception reporting

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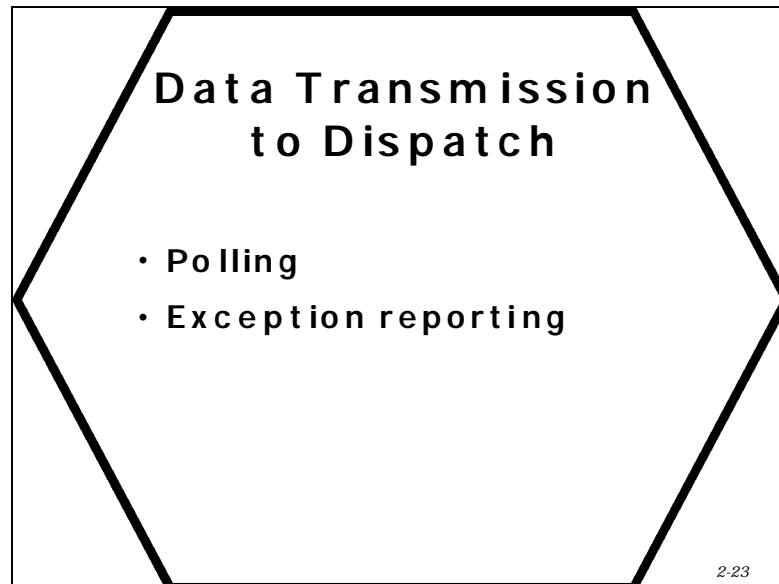
**Data trans-
mission to
dispatch**

The second essential part of an AVL system that combines with the location technology is transmitting the data to the dispatch center.

Data Transmission to Dispatch, Continued

Data transmission to dispatch

For transmission, an agency must decide whether to "piggy-back" the location data onto an existing voice or data radio network, or to use a stand-alone network.

- If an existing network is used,
  ◊ Delays can be experienced in communicating locations due to the higher volumes of traffic being transmitted.
  ◊ If the system is not designed properly, voice communications can also run into the data, causing the voice communications to be lost.

- For most fleets, a dedicated mobile radio system is often the more efficient choice.

- Microwave and cellular networks could also be used for data transmission, but they are very expensive or not secure or reliable enough for agencies to implement for AVL purposes.

- By automating data transmission to dispatch, you reduce the amount of voice information the operator must relay to dispatch.
  ◊ decreased voice traffic in telecommunications
  ◊ increased data burden on telecommunications systems
  ◊ Overall, telecommunications needs will increase.
  ◊ You must ask: can your existing system handle the increase?

Data Transmission to Dispatch, Continued

Polling

AVL systems collect short, frequent bursts of data.

The two primary methods of transmitting this data to the central dispatch are polling and exception reporting.

In polling, either the mobile data terminal (MDT) polls the central receiver or the dispatcher's computer polls the vehicle. This could be very data intensive, depending on dispatch's need for a given vehicle's location.

For example, a system could poll critical response units every 15 or 20 seconds, while polling non-critical units every 60 seconds.

Exception reporting

A related alternative, exception reporting, has the vehicle automatically reporting its position to dispatch only when it is off schedule or at certain spots along the way, whichever comes first.
• This greatly reduces the data loads on the communications link.

Data Transmission to Dispatch, Continued

Slide: State-of-the-Art Polling

> ### State-of-the-Art Polling
>
> - Computer at dispatch polls each bus for its location
> - Bus relays info
> - Cycle restarts after all buses are polled
> - Computer can poll over different radio channels
>
> *Transit Management 2-24*

Polling
Current solutions use a software routine that polls the vehicles for position. The polling rate is set to provide sufficient position updates for the fleet while at the same time not overloading the communication channel or the base-station computer.

- Polling tends to provide unnecessary data traffic because not all vehicles require constant position updates.

Several different methods to limit data traffic while still sampling enough known vehicle positions include:
- passive polling
- active polling
- selective polling

Data Transmission to Dispatch, Continued

Notes:

Data Transmission to Dispatch, Continued

**Slide: Polling
Advantages**

**Polling
advantages**

Polling data accuracy depends on how often the buses are polled. How often the buses are polled depends on fleet size.

- The larger the fleet the longer a polling cycle takes.
- Small fleets can use this technology efficiently.
- Cycle times can also depend on the number of transmission channels available.

Continued on next page

Data Transmission to Dispatch, Continued

Slide: Polling Disadvantages

```
                    ┌──────────────────────────────────┐
                    │         Polling                   \
                    │       Disadvantages                >
                    │                                   /
                    ├──────────────────────────────────┘
                    │  · Location accuracy depends on
                    │    how often the buses are polled
                    │
                    │  · Can create unnecessary data
                    │    traffic
                    │
                    │  · Can be very expensive for larger
                    │    fleets
                    │
                    │                    Transit Management 2-26
                    └──────────────────────────────────
```

Polling disadvantages

Too much polling can create too much data traffic.

- The larger the fleet the longer a polling cycle takes.
- Cycle times can also depend on the number of transmission channels available.
- If there is an increase in fleet size, the polling rate is set either at a longer time interval which holds communications constant, or the power of the communication channel and computer processor is increased to shorten the polling interval. This can be very expensive if a fleet grows.

Data Transmission to Dispatch, Continued

Slide: State-of-the-Art Exception Reporting

> # State-of-the-Art Exception Reporting
>
> · Bus reports location at a few points or when bus is off schedule or off route
>
> · Without a report, dispatch assumes bus is on schedule and in the correct location
>
> *Transit Management 2-27*

Exception reporting

Many transit agencies have chosen exception reporting to compensate for the disadvantages of polling.

With exception reporting, each vehicle reports its location to dispatch only at a specific point, or when the vehicle is running off schedule beyond specified parameters.
• If there is no report, dispatch assumes that the vehicle is on schedule.

Exception reporting requires each vehicle to know:
• its position
• its scheduled position

Continued on next page

Data Transmission to Dispatch, Continued

Notes:

Data Transmission to Dispatch, Continued

Slide: Exception Reporting Advantages

> ## Exception Reporting Advantages
>
> - More efficient use of available radio channels
> - More efficient than polling
> - Decreased transmission costs possible
> - Combination of polling and exception reporting often used
>
> *Transit Management 2-28*

Exception reporting advantages

Exception reporting makes more efficient use of radio channels.
- This can decrease transmission costs.
- This method is more efficient than polling.

Many agencies use a combination of polling and exception reporting to take advantage of both technologies.

Data Transmission to Dispatch, Continued

**Slide: Exception
Reporting
Disadvantages**

Exception Reporting
Disadvantages

· Increased costs per vehicle

Transit Management 2-29

**Exception
reporting
disadvantages**

- Exception reporting requires more software than polling because it is harder to do.
- The additional complexity increases costs per vehicle.

Many agencies use a combination of polling and exception reporting to take advantage of both technologies.

Examples

Slide: Examples

Transit Management 2-30

Transit fleet management

Transit fleet management is one of the nine multimodal Traveler Management and Traveler Information Components of ITS. Transit fleet management shares certain location technology equipment with other components such as Emergency Management and Freeway Management.

Many technologies employed in transit fleet management are related directly to transit, including signal priority control and AVL.
- AVL can give Transit Management Centers information regarding vehicle speeds and congestion levels.

Systems exist or are being implemented in many locations, including Anaheim, Denver, Detroit, Minneapolis, Houston, San Antonio, Seattle, and Milwaukee.

Examples, Continued

Montgomery County, MD

Montgomery County, Maryland has recently developed and implemented an advanced transportation system. This system manages public transportation flow by integrating transit management with the traffic signal system, without causing gridlock for other vehicle traffic. Buses are outfitted with global positioning systems (GPS) AVL which provides real-time transit information to the transportation management control center.

The entire system includes:
- Adaptive traffic signal control
- Automated signal control
- 200-camera surveillance system
- Automated transportation information
- Vehicle tracking (GPS and others)
- Aerial surveillance operations
- Integration with future automated highway systems

MnDOT

Minnesota Department of Transportation (MnDOT) Traffic Management Center has a number of projects that involve ITS for transit, under Minnesota Guidestar.

One effort, called the ARTIC (Advanced Rural Transportation Information and Coordination) project is testing the application of ITS technology in several public agencies in the rural Arrowhead region.

The project has an AVL and MDT component with functionality on 15 MnDOT vehicles, 4 Minnesota State Police vehicles and 15 transit buses. There is also an interface between the MDTs and the sand spreader control on the plow trucks.

For more information, see their extensive web site at
http://www.dot.state.mn.us/tmc/index.html

Examples, Continued

Ann Arbor, MI
AATA

At the end of 1997, the Ann Arbor Transportation Authority (AATA) gave final approval to a new radio backbone and AVL system for their entire revenue fleet – 70 fixed-route buses and ten paratransit vehicles.

System uses:
- Differential GPS
- Dead-reckoning
- Dispatch computer stations, which control:
  ◊ Fixed-route operations
  ◊ Paratransit operations
- GIS maps
- CAD
- Run-cutting software
- Real-time paratransit dispatching software

Vehicles are fitted with APTS equipment such as:
- Mobile data terminals
- Automatic monitors of engine components
- AVL-integrated farebox
- Internal and external digit signs and audible annunciators
- Automatic Passenger Counters (APCs)
- Security cameras

Examples, Continued

Slide:
Summary

Summary

Transit Management 2-31

Transit Management Training Course	Title	ITS Professional Capacity Building		NTI course
		Technical Seminars	Short Courses	
Module 2: Automatic Vehicle Location Systems	Geographic Information Systems: Transit Applications			x

TABLE 2-1: APTS AUTOMATIC VEHICLE LOCATION SYSTEMS TECHNOLOGY REFERENCE		
Technology	*Description*	*Benefits, Costs, and Risks*
State-of-the-art Location Technology		
Global Positioning System (GPS)	Technology which uses signals transmitted via a satellite network	• GPS works in a wide area at a relatively low cost • It can be interrupted by urban canyons or trees and will not work underground • Coverage is discontinuous • Accurate to 100 meters
Differential GPS	GPS system that uses a "known position" to account for errors in position	• Greatly improved accuracy over traditional GPS (to 20 meters or better)
Other Location Technology		
Signpost & Odometer	A series of radio beacons placed along the route send out a low powered signal detected by a receiver on the vehicle	• Earliest, most common technology that is well tested and reliable • Requires high maintenance and is limited by where signposts can be placed • The system cannot track vehicles off route
Radionavigation and radiolocation	Land-based radionavigation (LORAN C) and communication systems which use low frequency waves and triangulation	• Low cost and low maintenance and offers continuous coverage in all weather conditions • Triangulation offers improved accuracy • Susceptible to interference and is no longer widely used
Dead Reckoning	Vehicles determine their location from a known starting point by measuring distance traveled and by using an integrated compass	• The system has a 1 to 2 percent error rate, which is good for short distances. At large distances, the error adds up to a significant deviation. • Used in conjunction with Mapmatching and GPS to decrease error
Data Transmission to Dispatch		
Polling	A software routine at the central dispatch that polls the vehicle for its location	• Cycle times are dependent on fleet size, i.e., the larger the fleet, the longer it takes • Location accuracy is a function of polling frequency • Can create unnecessary data traffic
Exception Reporting	Vehicle reports its location at a few specific points or when off schedule	• More efficient use of radio channels • Requires more hardware and software than polling

Exercise 2-1: Custom Course Notes

In this exercise   You will:
- identify the challenges in your agency that can be addressed with AVL technologies
- identify the most appropriate AVL system for your agency
- identify the possible benefits of using Automatic Vehicle Location Systems in your transit systems

Directions   Read the example provided and answer the questions that follow.

Case Study: CTA   **Chicago Transit Authority**:

In April 1996, the Chicago Transit Authority (CTA) issued a Notice to Proceed on the installation of a combination dead-reckoning/GPS system on about 1,500 of its nearly 2,100 buses. CTA expects the installation to be complete before the fall of 1999. Because of the many tall buildings lining the streets of downtown Chicago, CTA is using a combination of dead-reckoning and GPS to enjoy the advantages of GPS, yet compensate for the times the GPS signals are blocked by buildings.

When the system is in place, CTA will initiate a demonstration project that will include a Bus Service Management System (see *Update '98*, Section 2.5.1), to aid dispatchers in correcting schedule deviations more quickly and easily.

The AVL will also include a Bus Emergency Communications System, a fully integrated communications base that enhances the effective delivery of bus service using a new two-way voice and data radio system (see *Update '98*, Section 2.5.1). CTA also operates APCs on 25 of its buses (see *Update '98*, Section 2.4). These are currently operated separately from the AVL, but the CTA is considering linking the two.

Source: APTS State-of-the-art Update '98, p. 2-20 to 2-21 and 2-37

Exercise 2-1: Custom Course Notes, Continued

Question 1   How is the Chicago example relevant to your transit system and your region?

Question 2   What elements of the Chicago example would you need to consider for your transit agency? for your region?

Question 3   What benefits did the Chicago example demonstrate? List benefits that would apply for your transit agency.

Exercise 2-1: Custom Course Notes, Continued

For more information

For additional information, use the following table to look up additional examples of what is going on in the field.

Automatic Vehicle Location Systems Examples			
Technology	**Story**	*Update '98*	**Additional info**
Combination systems	AATA in Ann Arbor, MI	p. 2-18	Differential GPS and dead reckoning
	NYCT in New York, NY	p. 2-21	Differential GPS and dead reckoning
GPS	Tri-Met in Portland, OR	p. 2-16	*Update '96,* p. 25
	RTD in Denver, CO	p. 2-17	*Update '96*, p. 24
Signpost and Odometer	King County Metro in Seattle, WA	p. 2-14	System was new in 1993. See also *Update '96,* p. 22
	New Jersey Transit in Newark, NJ	p. 2-15	New system (planning stage)